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Exploratory survey in China for potential insect biocontrol agents of mile-a-minute weed, *Polygonum perfoliatum* L., in Eastern USA

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Abstract

A survey was undertaken in China between 1996 and 2001 for phytophagous insect fauna associated with mile-a-minute weed, *Polygonum perfoliatum* L. (Polygonaceae). The purpose was to identify potential biological control agents for this invasive plant in the eastern USA. The survey covered 23 provinces including northeastern China, where the climate is similar to that of the eastern USA, and southwest China, which is considered the center of origin of the family Polygonaceae. About 111 insect species were collected and identified, although some immatures were not identified to species level. Based on information from the literature and results from laboratory and field tests on host range, severity of damage, and widely distributed field populations, a weevil, *Rhinoncomimus latipes* Korotyaev (Coleoptera: Curculionidae) was regarded as the most promising agent. Three oligophagous leaf beetles, *Smaragdina nigrifrons* (Coleoptera: Eumolpidae), *Gallerucida bifasciata* (Coleoptera: Chrysomelidae), and *Galerucella placida* (Coleoptera: Chrysomelidae), as well as a geometrid moth, *Timandra griseata* (Lepidoptera: Geometridiae), were dominant at most of the surveyed sites. All impacted the growth and reproduction of mile-a-minute weed. One bug, *Cletus schmidti* (Hemiptera: Coreidae), and one sawfly, *Allantus nigrocaeruleus* (Smith) (Hymenoptera: Tenthredinidae), are recommended for further evaluation for host specificity.

Keywords: Polygonum perfoliatum; Mile-a-minute; Exploratory survey; Natural enemies; Insects; China; Classical biological control

1. Introduction

Mile-a-minute weed, *Polygonum perfoliatum* L. (Polygonaceae), also known as devil's tail tearthumb, is an annual, or perennial herb. It is native to India, China, Korea, Japan, Bangladesh, and the Philippines (He et al., 1984; Holm et al., 1979; Kahn and Hassan, 1978; Li, S., 1988; Li, A., 1998; Ohwi, 1965). The plant has been used in Chinese medicine for over 300 years (Lou et al., 1988) and has rarely been recorded as an important noxious weed in either agriculture or the environment (Wang, 1990).

Mile-a-minute weed was introduced into the United States for unknown reasons. It was first reported near Portland, Oregon in the 1890s (Hickman and Hickman, 1977) and then in south central Pennsylvania in the 1930s (Moul, 1948). It did not establish permanent populations in either area (Oliver and Coile, 1994). The first successful established population of mile-a-minute weed was found in late 1930s following its introduction to a nursery site in York County, Pennsylvania and since then it has spread to neighboring states (Mountain, 1995). From 1930 to 1980s, mile-a-minute weed was only reported in five counties in Pennsylvania and northern parts of central Maryland (Mountain, 1995; Price, 2001; Reed, 1979a,b; Riefner and Windler, 1979). By 2003, mile-a-minute weed was found in eight states in the USA (Delaware, Maryland, New York, Ohio, Pennsylvania, Virginia, West Virginia, and Connecticut) and the District of Columbia (Lamont and Fitzgerald, 2000; Price, 2001). Mile-a-minute weed was also

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reported in British Columbia, Canada (Hill et al., 1981) where populations failed to establish.

Infestations of mile-a-minute weed cause ecological problems in invaded areas. It has been placed on several state noxious weed lists in the United States (Oliver and Coile, 1994; Wu et al., 2002). Mile-a-minute weed grows rapidly and covers shrubs and other vegetation, dominating in its new community. Plants and trees covered with mile-a-minute weed are greatly suppressed because of the lack of sunlight. Mile-a-minute weed can also cause economic losses after it invades orchards, nurseries, and horticultural crops as the plant can smother seedlings (Okay, 1997). Since leaves, petioles, and stems of mile-a-minute weed contain prickles, the movement of wildlife, and human activities are impacted in infested areas (Okay, 1997).

Okay (1997) reported that mile-a-minute weed has the potential to spread to 15 additional states which have climates conducive for the survival of mile-a-minute weed. Also, mile-a-minute weed could eventually spread into the southern states where it may persist as a perennial (Stevens, 1994). In Asia, mile-a-minute weed has a broad geographical range from northeastern to southeastern Asia (subtropical or tropical climates) (Ding et al., 2000; Li, 1998).

Manually removing mile-a-minute weed is a viable control option when the plant is in the seedling stage but becomes more difficult when the plant has grown and becomes tangled with other vegetation (Mountain, 1995). Since it always grows together with other plant species, glyphosate-based herbicides will kill other plants as well. Environmental concerns will also be another strict limitation for the use of herbicides in a large infested or sensitive (e.g., riparian zones) areas.

The first survey for natural enemies of mile-a-minute weed in the United States was conducted in the 1980s. Wheeler and Mengel (1984) reported approximately 30 insect species recovered from minute-a-minute weed in Pennsylvania but none appeared to cause sufficient damage to slow the weed's spread or reduce its populations. Fredericks (2001) surveyed for natural enemies of mile-a-minute weed at selected sites in Delaware and Maryland during 1997–1998 and found the polyphagous Japanese beetle *Popillia japonica* Newman (Coleoptera: Scarabaeidae) to be the most damaging insect. *P. japonica* was reported on mile-a-minute weed soon after the weed was discovered in Pennsylvania (Moul, 1948). In cooperation with State Departments of Agriculture and Forestry of Delaware, Maryland, Virginia, and Pennsylvania, the USDA Forest Service led a project from 1997 to 2000 to survey insect species at 50 sites across the four states. A total of over 2000 insect specimens in 112 families and 7 orders were collected and identified at 35 sites, among which the Japanese beetle was the most abundant herbivorous species recorded (Richard Reardon et al., unpublished data).

Little information was available concerning the natural enemies of mile-a-minute weed in its native areas. *Gastrophysa atrocyanea* (Coleoptera: Chrysomelidae) was reported attacking mile-a-minute weed in Jiangsu, southeast China but preferred *Polygonum aviculare* L., *Rumex japonicus* Houtt., *R. crispus* L., and *R. dentatus* L. in Polygonaceae (Lei et al., 1994; Wang, 1991; Wang and Chen, 1988). In 1996, a collaborative project was initiated between the Institute of Biological Control, Chinese Academy of Agricultural Sciences and the USDA Forest Service to survey for and screen potential biocontrol agents in China for release against mile-a-minute weed in the United States. Ding et al. (2000) reported on the preliminary results for surveys conducted from 1996 to 1998 in 12 provinces in China. The purpose of this paper is to report in detail the results of the surveys in China from 1996 to 2001 and to provide a list of phytophagous insects found.

2. Materials and methods

2.1. Selection of field survey sites

Mile-a-minute weed is widely distributed in 23 provinces in China (Li, 1998). Therefore, field sites were divided into three priority areas (Fig. 1): (1) Liaoning, Hebei (including Beijing, Tianjin), Henan, and Shandong provinces located in north and northeastern China, where the climate is similar to the eastern USA where mile-a-minute weed has invaded. Collections were made at 4–10 sites in each province at intervals of 2–4 weeks in 1 or 2 field seasons over 3–4 years. (2) Yunnan, Guangxi, and Sichuan (including Chongqing) provinces located in Southwest China which are regarded as the original regions of the family Polygonaceae in China (Zhang and Zhou, 1997). Four to 10 field sites in each province were visited once or twice at different times over 3–4 years. (3) Other provinces of China where mile-a-minute weed is also distributed. Field surveys were conducted at 3–10 sites in these areas once or twice during the project.

2.2. Collection, rearing, and identification of insects

Insect specimens were hand-picked from plants at each survey site. In addition to the leaves, attention focused on the important parts of the plant (e.g., root, stem, flowers, seeds) to recover root- and stem-borers, internal fruit-feeders, or gall-makers. Type and severity of damage on the plant as well as relevant biological information of natural enemies were recorded. Larvae were reared to adults in the laboratory.

Adult and nymph specimens of Hemiptera–Heteroptera were sent to the Department of Entomology, Nankai University, Tianjin, and all other adults were

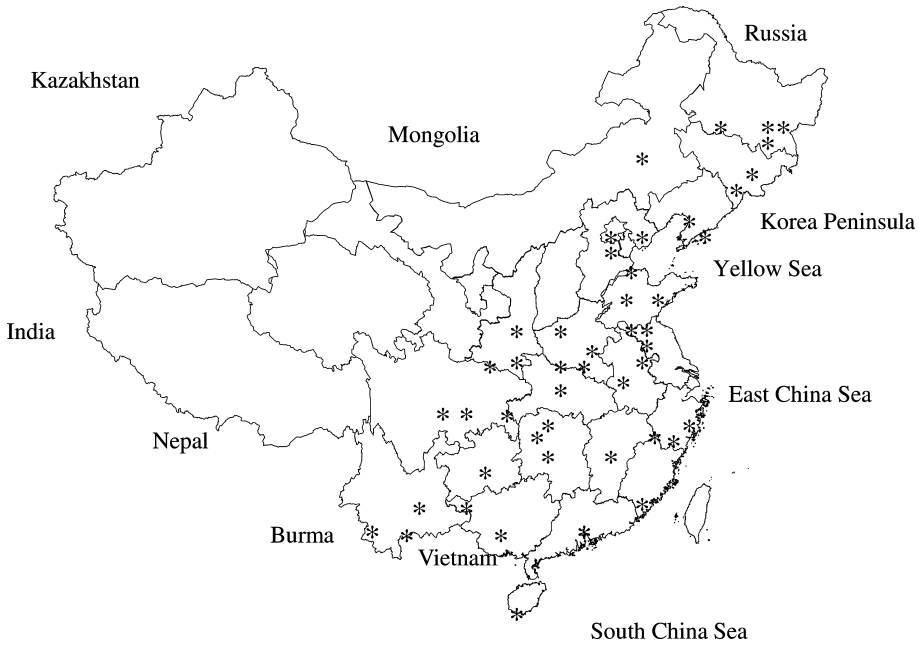

Fig. 1. The major survey areas (*) in China.

identified by insect taxonomists at the Zoology Institute, Chinese Academy of Sciences, Beijing, China. Larval specimens were sent to West Virginia University, USA. Most of the specimens were returned and are preserved in the collection of the Institute of Biological Control, Chinese Academy of Agricultural Sciences. Specimens of some species were retained by taxonomists who identified them.

All identified phytophagous insects were evaluated based on their host ranges, pest status, frequency of occurrence on mile-a-minute weed, and geographical distribution by consulting with entomologists knowledgeable about the particular species or group and literature review. Field observations were conducted for some key insect species, e.g., *Rhinoncomimus latipes*, *Timandra greastea*, *Smaragdina nigrifrons*, *Gallerucida bifasciata* for their host ranges in nature.

3. Results

3.1. General analysis

The phytophagous fauna associated with mile-a-minute weed in China is listed in Table 1. A total of 111 species representing six orders and 29 families were recovered. The orders represented were Coleoptera (60; 54.1%), Hemiptera–Heteroptera (28; 25.2%), Lepidoptera (19; 17.1%), Hymenoptera (2; 1.8%), Homoptera (1; 0.9%), and Orthoptera (1; 0.9%). Several immature specimens of Phlaeothripidae (Thysanoptera) and Scolytidae (Coleoptera) were identified only to family level and are not included in this list. Although most of the insects were recovered from leaves, several stem-borers, fruit- and seed-feeder(s) were found (the identification of the seed-feeding larvae to species level was not available). No insects were recovered from roots.

3.2. Notes on important species

Among the fauna associated with mile-a-minute weed in China, 11 were regarded as important because of either their severe damage on mile-a-minute weed or narrow host range.

3.2.1. Rhinoncomimus latipes (Coleoptera: Curculionidae)

Adults of *R. latipes* were collected from the upper petiole and on the upper surface of the lamina, particularly on the first or second youngest leaf of the mile-a-minute weed plant. Newly emerged adults are black but become orange later. Adults fed externally by scraping the epidermal layer and some of the underlying cells usually penetrating through the leaf in the shape of a feeding hole. Eggs could be found on the young leaves and tender buds, rarely on older leaves, and the stem. Eggs are buff colored, ovoid, and kidney shaped. The larvae are uniformly yellow with a light brown head capsule. Newly hatched larvae bore into the young stem or bud from the top of the plant and tunnel downwards inside the stem. Heavy defoliation by adult weevils on the lamina and boring by larvae caused leaves to desiccate and curl and young shoots to wither away. This weevil was collected in nine provinces, Heilongjiang,

Table 1
The phytophagous insects associated with *P. perfoliatum* in China

Order/ Family	Species	Relative frequency[a]	Stages found[b]	Plant part	Host range[c]	Pest status[d]
Coleoptera						
Rutelidae	*Anomala cupripes* Hope	R	A	Leaf	Po	*
	Anomala virens Lin	R	A	Leaf	Po	*
	Blitopertha pallidipennis Reitter	R	A	Leaf	Po	
	Callistethus plagiicollis Fairmaire	R	A	Leaf	Po	
	Popillia mutans Newman	R	A	Leaf	Po	*
	Popillia quadriguttata Fabricius	O	A	Leaf	Po	*
Curculionidea	*Apoderus erythropterus* Zsclath	O	A	Leaf	Unknown	
	Calomycterus obconicus Chao	R	A	Leaf	Po	
	Gasteroclisus klapperichi Voss	R	A	Leaf	Po	
	Rhinoncomimus latipes Korotyaev	C	L, A	Leaf, bud, stem	Mo	
	Hypera basalis Voss	R	A	Leaf	Po	
	Lixus amurensis Faust	R	A		Po	
	Phrytpscaphus triangularis Olivier	R	A	Leaf	Po	
	Piazomias dilaticollis Chao	O	A	Leaf	Unknown	
Bruchidae	Callosobruchus chinensis (L.)	R	A	Leaf	Po	*
Coccinellidae	Henosepilachna operculata (Liu)	R	A	Leaf	Po	
Eumolpidae	*Aoria scutellaris* Pic	R	A	Leaf	Po	
	Basilepta leechi (Gacoby)	R	A	Leaf	Po	
	Chrysochus chinensis Baly	R	A	Leaf	Po	
	Cryptocephalus pustulipas Menetries ab. Multiplex Suffr.	R	A	Leaf	Po	
	Platycorynus sp.	R	A	Leaf	Po	
	Smaragdina nigrifrons (Hope)	C	L, A	Leaf, fruit	Po	
Meloidae	*Epicauta tibialis*	R	A	Leaf	Po	*
Cleridae	*Trichodes* sp.	R	A	Leaf	Po	
Lilioceridae	*Lema diversa* Baly	R	A	Leaf	Ol	
	Lema concinnipennis Baly	R	A	Leaf	Ol	
Chrysomellidae	*Altica coerulea* Olivier	R	A	Leaf	Po	
	Altica sp.	R	A	Leaf	Unknown	
	Apophylia flavovirens (Fairmaire)	R	A	Leaf	Po	
	Atrachya menetriesi (Faldermann)	R	A	Leaf	Po	
	Aulacophora indica (Gmelin)	O	A	Leaf	Po	*
	Aulacophora sp.	R	A	Leaf	Unknown	
	Cassida nebulosa L.	R	A	Leaf	Po	
	Chrysolina anrichalcea Mann.	R	A	Leaf	Po	
	Chrysolina virgata (Motschulsky)	R	A	Leaf	Po	
	Chrysomela salicivorax (Fairmaire)	C	A	Leaf	Po	
	Colasposoma dauricum Mannerheim	R	A	Leaf	Po	
	Creophilus maxillosus (L.)	R	A	Leaf	Po	
	Demotina fasciculata Baly	R	A	Leaf	Po	
	Gallerucida bifasciata Motschulsky	C	L, A	Leaf	Po	
	Galerucella grisescens (Joannis)	O	L, A	Leaf	Ol	*
	Gastrolina depressa thoraciea Baly	R	A	Leaf	Po	
	Hemipyxis plagioderoides (Motschulsky)	R	A	Leaf	Unknown	
	Humloa cyanieollis (Hope)	R	A	Leaf	Po	
	Laccoptera quadrimaculata quadrim (Thunberg)	R	A	Leaf	Po	
	Luperomorpha xanthodera Fairum.	R	A	Leaf	Po	
	Mimastra limbata Baly	R	A	Leaf	Po	
	Monolepta hieroglyphica (Motschulsky)	C	A	Leaf	Po	
	Nonarthra cyaneum Baly	R	A	Leaf	Po	
	Phygasia ornata Baly	R	A	Leaf	Po	
	Platycorynus Peregrius (Herbst)	R	A	Leaf		
	Playiodera versicolora (Laicharting)	R	A	Leaf	Po	
	Potanina assameusis Baly		A	Leaf		
	Psylliodes punctifrons Baly	R	A	Leaf	Po	*
	Pyrrhalta sp.	R	A	Leaf	Unknown	
	Taiwania circumdata (Herbast)	R	A	Leaf	Unknown	

Table 1 (*continued*)

Order/ Family	Species	Relative frequency[a]	Stages found[b]	Plant part	Host range[c]	Pest status[d]
Hispidae	*Dactylispa angulosa*	R	A	Leaf	Po	
Cerambycidae	*Phytoecia ruliventris* Gautier	R	A	Stem	Po	
Buprestidae	*Coraebus aeneicollis* Kerr	R	A		Unknown	
	Coraebus spp.	R	A		Unknown	
Hemiptera-Heteroptera						
Aanthosomatidae	*Elsmasetethus humeralis* Jakovelev	R	A	Leaf	Po	
Alydidae	*Riptortus pedestris*	R	A		Po	*
Coreidae	*Cletus bipunctatus* (Herrich-Schaefer)	O	A	Fruit	Po	
	Cletus punctiger Dallas	O	A	Fruit	Po	*
	Cletus punctulatus Westwood	O	A		Po	
	Cletus schmidti Kiritschenko	C	N, A	Leaf, fruit	Ol, Mo ?	
	Coreus marginatus orientalis Kiritschenko	O	N	Leaf	Po	
	Homoeocerus dilatatus Horvath	R	A	Leaf	Po	
	Hygia touchei Distant	C	A	Leaf	Po	
Miridae	*Adelphocoris nigritylus* Hsiao	O	N, A	Leaf	Po	
	Ectmetopterus micantulus (Horvath)	R	A	Leaf	Unknown	
	Crenotidaes sp.	R	A	Leaf	Unknown	
Plataspidae	*Coptosomo parvippicta* Montandon	R	A	Leaf	Po	
Rhopalidae	*Rhopalus maculatus* (Fiebert)	R	A	Leaf	Po	*
	Stictopleurus minutus Blote	?	A	Leaf	Unknown	
Pentatomidae	*Carbula putoni* (Jakollev)	R	A	Leaf	Unknown	
	Dolycoris baccarum (Linnaeus)	R	A	Leaf	Po	*
	Erthesina fullo (Thunberg)	R	A	Leaf	Po	*
	Eurydema dominulus (Scopoli)	O	A	Leaf	Po	
	Eurydema gebleri Kolenati	R	A	Leaf	Po	
	Eysarcoris annamita Breddin	O	A	Leaf	Unknown	
	Eysarcoris parvus (Uhler)	R	A	Leaf	Unknown	
	Halyomorpha halys (Stal)	R	A	Leaf	Po	
	Megymenum gracilicornis Dalls	R	A	Leaf	Po	*
	Menida violacea Motshculsky	R	A	Leaf	Po	*
	Palomena virdissima Poda	R	N	Leaf	Po	
Lygaeidae	*Tropidothorax elegans* (Distant)	R	A	Leaf	Po	
	Nysius sp.	R	A	Leaf	Unknown	
Lepidoptera						
Geometridae	*Ectropis* sp.	R	A	Leaf	Po	
	Scopula superior (Butler)	R	A	Leaf	Unknown	
	Timandra convectaria Walker	C	A, L	Leaf	Ol	
	Timandra griseata Petersen	C	L, P, A	Leaf	Ol ?	
Noctuidae	*Acronicta rumicis* Linnaeus	O	L	Leaf	Po	
	Argyrogramma agnata Staudinger	C	L	Leaf	Po	*
	Parallelia stuposa Fabricius	O	L	Leaf	Po	
	Spodoptera exigua (Hubner)	O	L	Leaf	Po	
	Trachea atriplicis Linnaeus	C	L	Leaf	Po	
Pyralidae	*Coclebotys coclesalis* (Walker)	R	L	Leaf	Unknown	
	Notarcha derogata (Fabricius)	R	L	Leaf	Po	
	Ostrinia scapulalis (Walker)	C	L, A	Stem	Po	*
	Pleuroptya ruialis (Scopoli)	C	L	Stem	Po	
Tortricidae	*Adoxophyes orana* Fischer von Roslerrtamm	O	L	Leaf	Po	*
	Archips eucroca Diakonoff	R	L	Leaf	Po	
	Cerace xanthochocosma Diakonoff	R	L	Leaf	Po	
Hesperiidae	Ampittia nana (*Leech*)	R	L	Leaf	Unknown	
Notodonidae	Cloetera anachoreta (*Fabricius*)	R	L	Leaf	Po	
Arctiidae	*Hyphantria cunea* (Drury)	C	L	Leaf	Po	*
Hymenoptera						
Tenthredinidae	*Allantus fusipennis* (Smith)	O	A	Leaf	Po	
	Allantus nigrocaeruleus (Smith)	O	A	Leaf	Ol	

Table 1 (*continued*)

Order/Family	Species	Relative frequency[a]	Stages found[b]	Plant part	Host range[c]	Pest status[d]
Homoptera						
Fulgoridae	*Lycorma delicatula* (White)	O	A	Leaf	Po	
Orthoptera						
Acrididae	*Xenocatamtops brachycezne* (Will)	R	A	Leaf	Unknown	

[a] R, rare, taken at one or two sites in one or two provinces, usually in small numbers; O, occasionally collected at two or more sites in one or two provinces; C, common, taken at most sites in more than two provinces.

[b] L, larva; P, pupa; A, adult; N, nymph.

[c] Po, polyphagous species from other families; Ol, oligophagous species occurring mainly on Polygonaceae; Mo, monophagous on mile-a-minute weed.

[d] Asterisk indicates that the species is a known economic pest.

Liaoning, Henan, Hubei, Hunan, Shannxi, Guizhou, Zhejiang, and Guangdong, from northeastern to southern China.

No other plant species was found to be attacked by the weevil during all the field surveys in China. Choice, no-choice, and open-field tests for the weevil were conducted with more than 50 plant species from 17 families in China from 1999 to 2002 (Ding Jianqing et al., unpublished data). No-choice tests showed both the adult and larva fed only on plant species in the family Polygonaceae, namely *R. japonicus* Houtt, *Rheum altaicum* A. Los., *P. lapathifolium* L., and *P. bistorta* L. Adult longevity on those plants was from 3 to 25 days but 69 days on mile-a-minute weed. Choice-tests in which, *Fagopyrum esculentum* Moench, *Fagopyrum tataricum* (L.) Gaertner, and *Polygonum thunbergii* Siebolb and Zuccarini, were inter-planted together with mile-a-minute weed in an open field showed that adults only attacked mile-a-minute weed, although the holotype of *R. latipes* was reportedly collected from *P. thunbergii* Seibold and Zuccarini in the Russian Far East (Korotyaev, 1997). Based on this information, this weevil was introduced into quarantine in the USA in 1999. Price et al. (2003) reported that in no-choice tests, the adult *R. latipes* fed on common buckwheat (*F. esculentum*) and rhubarb (*Rheum rhabarbarum* L.), but consumed significantly more mile-a-minute weed foliage than the other two plant species. No eggs were laid on buckwheat or rhubarb in this 8-week test, while an average of over 130 eggs per female was laid on mile-a-minute weed. In a choice test, newly emerged *R. latipes* adults strongly preferred mile-a-minute weed to buckwheat and rhubarb. Also, when neonate larvae of *R. latipes* were placed on the three hosts, 75% of those placed on mile-a-minute weed survived to pupation, while all neonates died within 24 h on common and tartary buckwheat (*F. tataricum*), and rhubarb (Price et al., 2003).

3.2.2. Smaragdina nigrifrons (Hope) (Coleoptera: Eumolpidae)

Larvae and adults of this beetle were found feeding on young leaves and buds of mile-a-minute weed in Chongqing, Henan, Zhejiang, and Hunan provinces. When heavily grazed by the beetle, only petioles remained in the upper part of shoots of mile-a-minute weed. This beetle has at least 4 recorded host species outside of Polygonaceae (Wang et al., 1996).

3.2.3. Gallerucida bifasciata Motschulsky (Coleoptera: Chrysomelidae)

Larvae and adults of this leaf beetle were collected on the leaves of mile-a-minute weed in Liaoning, Heilongjiang, Henan, Shandong, Hunan, and Zhejiang provinces. Although the beetle could cause great damage to the plant, its broad host range limited its further use for biological control. Buckwheat (*F. esculentum*) and rhubarb (*R. altaicum*) were recorded as its hosts in China as well (Wang et al., 1996).

3.2.4. Galerucella placida Baly (Coleoptera: Chrysomelidae)

Larvae and adults of this beetle fed on leaves of mile-a-minute weed in almost all the sites in China. It was also found attacking other plant species of the family Polygonaceae, e.g., *P. lapathifolium*, and *P. hydropiper*. Field observation showed its host range was restricted to Polygonaceae. Cheng (1985) reported that it did not attack strawberry in nature, but could complete its life cycle on this plant in laboratory.

3.2.5. Timandra griseata (Lepidoptera: Geometridae)

Larvae were collected on leaves, including upper and middle petiole of mile-a-minute weed plants. This geometrid moth caused serious damage to mile-a-minute weed at most of the survey sites in China. The larvae of this moth fed on leaves, young buds, and fruits of mile-a-minute weed. When populations were high, they could destroy almost all the green leaves, and buds of one plant. It also occurs in Europe where its larvae were reported to feed on orache (*Atriplex* sp.), common sorrel and dock (*Rumex* sp.), and knotgrass (*Polygonum* sp.) (Skinner, 1998; Skou, 1986; South, 1980). Host-range tests both in China and USA showed that it preferred mile-a-minute weed, but also attacked buckwheat

(*F. esculentum*, and *F. tartaricum*) and rhubarb (*R. palmatum*) (Price et al., 2003; Ding Jianqing et al., unpublished data). Buckwheat and rhubarb are of economic importance in the USA.

3.2.6. Trachea atriplicis L. and Acronicta rumicis L. (Lepidoptera: Noctuidae)

Larvae of both of these noctuids were collected from leaves of mile-a-minute weed in Hebei, Beijing, and Liaoning provinces. Although older instar larvae consumed large amount of leaves, their broad host range limited their potential use for biological control of mile-a-minute weed (Anonymous, 1987).

3.2.7. Cletus schmidti Kiritehenko (Hemiptera: Coreidae)

This bug was collected on leaves and fruits of mile-a-minute weed throughout the survey areas. It sucked the skin of immature fruit of mile-a-minute weed that might eventually influence seed germination. Its host range is restricted to plants of Polygoneceae (Zheng Leyi, Nankai University, China, personal communication).

3.2.8. Pleuroptya ruialis (Scopoli) and Ostrinia scapulalis (Walker) (Lepidoptera: Pyralidae)

Larvae of both of these two pyralids were collected from stems of mile-a-minute weed, where they bored and formed galls. The shoots might wither and die because of the galls. Both moths are polyphagous and are pests of some important crops such as maize (Anonymous, 1987).

3.2.9. Allantus nigrocaeruleus (Smith) (Hymenoptera: Tenthredinidae)

This sawfly was collected from younger leaves and buds of mile-a-minute weed in Chongqing. Its host range was reported restricted in the family of Polygoneceae but detailed information was not available (Anonymous, 1987). It may warrant further study.

4. Discussion

Mile-a-minute weed is widely distributed in 23 provinces in China. With regard to the survey areas for natural enemies of invasive weeds one principle of conventional biocontrol theory is that greatest diversity of natural enemies exists in the center of origin and diversification of the target weed and another emphasizes that collection should be made from the climatic regions similar to those in which agents are likely to be released (Andres et al., 1976; Harley and Forno, 1992; Wapshere, 1974). In the case of mile-a-minute weed, both of the two regions were selected as first or second priority areas for the present survey. Southwestern China (e.g., Yunnan, Sichuan, and Guizhou provinces) represents the center origin of Polygonaceae (Zhang and Zhou, 1997) and climate of northeastern China (e.g., Heilongjiang, Jilin, and Liaoning provinces) is similar to northeastern United States where mile-a-minute weed has invaded. As mile-a-minute weed occurs more often in southern (e.g., Guangdong) and eastern China (e.g., Fujian and Zhejiang), survey was also conducted on a few sites in those areas although large regions remain unexplored.

One hundred and eleven phytophagous insect species were recovered from mile-a-minute weed in the present survey. Besides the limited areas surveyed, there may be many other factors that influence the insects associated with mile-a-minute weed. It has been reported that mile-a-minute weed had been used in traditional Chinese medicine for hundreds years to cure snake bite (He et al., 1984). Some local common names of mile-a-minute weed in Chinese, e.g., "She Bu Guo" and "She Dao Tui," mean the snake could avoid being close with the plant. This suggests that some special biochemical attributes of mile-a-minute weed may exist, which could also limit insects feeding on mile-a-minute weed.

Due to its host specificity and severe damage on mile-a-minute weed, the weevil, *R. latipes* was considered the most promising biological control agent against this weed. This weevil is distributed widely in 9 provinces from north to south China, which indicated that this potential biocontrol agent may have strong ecological flexibility. It even occurred frequently in Heilongjiang province, northeast China where the lowest temperature in winter could be minus 30–40 °C. This suggests that it could tolerate the cold winter climatic conditions in the eastern United States.

Cletus schmidti could be another promising biocontrol agent as it has a limited host range in Polygonaceae (Zheng Leyi, Nankai University, China, personal communication) and occurred often in high numbers on mile-a-minute weed in China. Its damage on fruits may suppress the reproduction of mile-a-minute weed and prevent the weed from invading additional areas. Little information is available about its biology and ecology. Choe and Cheol (1992) collected it in a weedy field in Korea but its host was not given in detail. Its host specificity should be determined in the near future to understand its potential as a biological control agent.

Phytophagous beetles comprised more than half of the total fauna associated with mile-a-minute weed in the present survey. Among them, one monophagous weevil, *R. latipes* was considered most promising agent against mile-a-minute weed and three other oligophagous leaf beetles *S. nigrifrons*, *G. bifasciata*, and *G. placida* were dominant at most of the surveyed sites.

Gastrophysa astrocyanea was not recovered from mile-a-minute weed although this leaf beetle was reported attacking mile-a-minute weed and to have a limited host range in Polygonaceae (Lei et al., 1994; Wang, 1991). In late April and early May in Southern

China, this univoltine beetle occurred on *P. aviculare* and *R. japonicus* in very high numbers, and could completely defoliate the plants. However, it began its diapause while mile-a-minute weed was only in the seedling stage. Hence, it is unlikely that this beetle could use mile-a-minute weed as its major host plant.

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